LETTER

Selective Scanning Scheme for Femtocells in IEEE 802.16e Systems

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SUMMARY Femtocell is considered a promising solution for indoor service enhancement in IEEE 802.16e cellular systems. However, the scanning scheme of IEEE 802.16e is not suitable for direct use in scanning femtocells in terms of efficiency and scan duration. In this paper, we propose an efficient scanning scheme for femtocells in IEEE 802.16e systems. The proposed scheme can achieve a lower scanning overhead by reducing the number of femtocells needed to be scanned. Numerical results show that the proposed scanning scheme can reduce the control message overhead and the scan duration.

key words: *scanning, handover, femtocell, IEEE 802.16e*

1. Introduction

In recent years femtocells have gained a lot of attention due to their advantages in terms of deployment cost saving and improved user experience in indoor environments. In IEEE 802.16e systems, an MS scans neighboring BSs to find an appropriate target BS for the next handover [1]. In dense urban areas, there may be hundreds of femtocells collocated in a single macro BS coverage area. If the existing scanning scheme of IEEE 802.16e is applied to femtocells, the size of the periodic neighbor advertisement message (MOB_NBR-ADV) will be very large. This causes a serious waste of wireless resources because the MOB_NBR-ADV message is broadcasted periodically to all the MSs in the cell. Moreover, the scan duration and handover delay can be drastically increased because the MSs should scan all the BSs in the neighbor list. In addition, the power consumption of the MSs can be also increased.

Much research has been done on reducing the scanning overhead [2]–[5]. However, they are based on the approach that the macro BS manages all the femtocells in the macrocell. Thus, they lack scalability because of the computational overhead and the complexity. Also, they do not consider the access control policy of the femtocell. The femtocell can be classified into two types based on the access control policy. The closed subscriber group (CSG) femtocell is accessible only to the member of the CSG and the open subscriber group (OSG) femtocell is accessible to any MS [6]. However, in the existing algorithms access control policy is not taken into account. Therefore, we propose efficient scanning schemes which are capable of reducing the number of femtocells to be scanned for both CSG and OSG femtocells.

2. Selective Scanning Scheme

We propose two selective scanning schemes applicable to CSG and OSG femtocells, respectively. In the proposed scheme, the MSs can recognize the existence of the CSG femtocells by monitoring BS ID of overlaid macro BS. Then the MSs only need to include the information of the CSG femtocell in the scanning request message. For the OSG femtocells, we propose that the OSG femtocells monitor the existence of MSs by energy detection [7], [8], and the MOB_NBR-ADV message contains the information of the OSG femtocells which detected MS instead of the information of all the OSG femtocells.

2.1 The Scanning Scheme for CSG Femtocells

Every MS maintains CSG white list that contains the BS ID of the CSG femtocells for which the MS is a CSG member [6]. We assume that the MS retrieves not only the information of the femtocell, but also the BS ID of the overlaid macro BS during a pre-authorization procedure. This assumption is reasonable because the femtocell knows the BS ID of the overlaid macro BS, and it may not be changed frequently. The scanning scheme for the CSG femtocells is as follows.

1. When an MS is handed over to a macro BS, the MS compares the BS ID of the macro BS with the BS IDs in the CSG white list to determine whether the accessible CSG femtocell is in the macrocell or not.
2. If the BS ID of the macro BS is in the list, the MS sends a MOB_SCN-REQ message which includes the scanning request for the CSG femtocell to the serving BS.
3. The serving BS, which received the MOB_SCN-REQ message, allocates the scanning interval for the MS by sending a MOB_SCN-RSP message.
4. The MS scans the BSs in the MOB_SCN-RSP message, and then reports the scanning results by sending a MOB_SCN-REP message.

The macro BS does not need to manage and broadcast

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the information of the CSG femtocells because the MS has that information. The macro BS needs only to allocate the scanning interval as requested by the MS. Consequently, the scanning overhead can be reduced.

2.2 The Scanning Scheme for OSG Femtocells

Unlike the CSG case, the MSs do not have any information about the OSG femtocells. In order to provide the information to the MSs, the macro BS should broadcast access information of the OSG femtocells by sending an MOB_NBR-ADV message. However, the broadcasting of the information of all the OSG femtocells in the macrocell causes a waste of wireless resources. In addition, since the MS may scan all the BSs in the MOB_NBR-ADV message, the scanning overhead can be so large that it may affect the performance of the whole network.

If no MSs are in the coverage of an OSG femtocell, the information of the OSG femtocell need not be broadcasted. In the proposed scheme, the macro BS broadcasts the information of the OSG femtocells which detected MSs in their coverage area instead of the information of all the OSG femtocells. The scanning scheme for the OSG femtocells is depicted in Fig. 1. It works as follows.

1. The OSG femtocell monitors the uplink signal of the MSs in the coverage area by using energy detection [7], [8]. If the uplink signal strength is higher than the threshold value and lasts longer than the reference time, then the OSG femtocell sends an MS_detected message to the macro BS. The MS_detected message includes the system information of the femtocell.
2. The macro BS now has a list of the OSG femtocells that detected the MSs in their own coverage area. The macro BS broadcasts an MOB_NBR-ADV message including the information of both the neighboring BSs and the neighboring OSG femtocells.
3. The MS requests an allocation of scanning interval by sending a MOB_SCN-REQ message to the serving BS.
4. The macro BS, which received the MOB_SCN-REQ message, will allocate the scanning interval for the MS by sending a MOB_SCN-RSP message.
5. The MS scans each BSs in the MOB_SCN-RSP message and reports the scanning results by sending a MOB_SCN-REP message.
6. If there is no more uplink signal from the MS, then the OSG femtocell sends a Femto_IDLE message to the macro BS.
7. The macro BS, which received the Femto_IDLE message, removes the femtocell from the neighbor list.

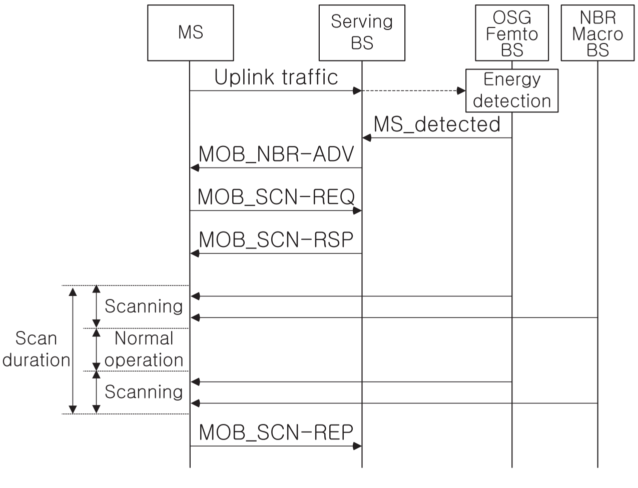

Fig. 1 Scanning scheme for OSG femtocells.

Since the MS only scans the selected femtocells rather than scanning all of the femtocells in the macrocell, the size of the control messages and the time consumed to complete the scanning can be reduced. Since the proposed scheme depends on the MS detection at the OSG femtocells using uplink signal, a monitoring error can occur when the MS is in idle mode or the uplink signal is weak. When the monitoring error occurs, the OSG femtocell will not be included in the neighbor list. That is, the MS lose a chance to handover to the OSG femtocell until the MS receives next MOB_NBR-ADV message. However, in many cases, macro-to-femto handover is not imperative. Generally, it is for better performance or particular preference. Therefore, the monitoring error does not lead to critical performance degradation. Also, it does not have an influence on scan duration, because the scan duration is mainly dependent on the number of BSs to scan.

3. Performance Analysis

This section analyzes the performance of the proposed scheme in terms of control message overhead, scan duration, and user throughput. We compare the performance of the proposed scheme with those of the existing scanning scheme of IEEE 802.16e [1] and the two-step scanning scheme proposed in [5].

3.1 Control Message Overhead

The MOB_NBR-ADV message is periodically broadcasted while the other messages are unicasted. We define the broadcasting control message overhead as the total size of the MOB_NBR-ADV messages needed to complete the scanning procedure. And we define the unicasting control message overhead as the total size of the control messages which are unicasted — MOB_SCN-REQ, MOB_SCN-RSP, and MOB_SCN-REP. The numerical results are obtained with the following assumptions: (i) there are 18 neighboring macro BSs, (ii) the number of CSG femtocells is equal to the number of OSG femtocells, (iii) a half of the OSG femtocells detect MSs in their coverage area, (iv) the number of MSs per macrocell is 300 [9].

Each control message can be divided into two parts. One part consists of message fields containing control information of scanning operation, such as Scan duration, Interleaving interval, Report mode, etc. The size of this part

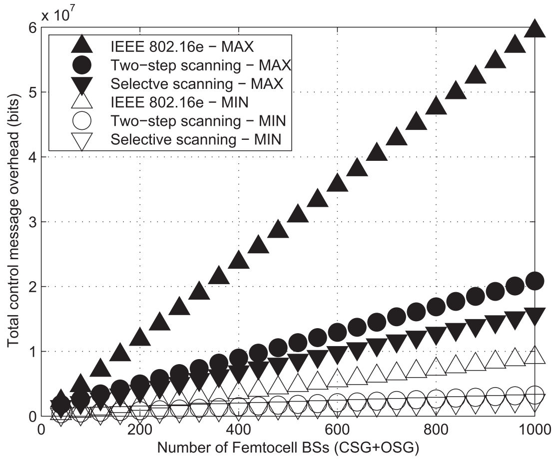

Fig. 2 Total control message overhead in a macrocell.

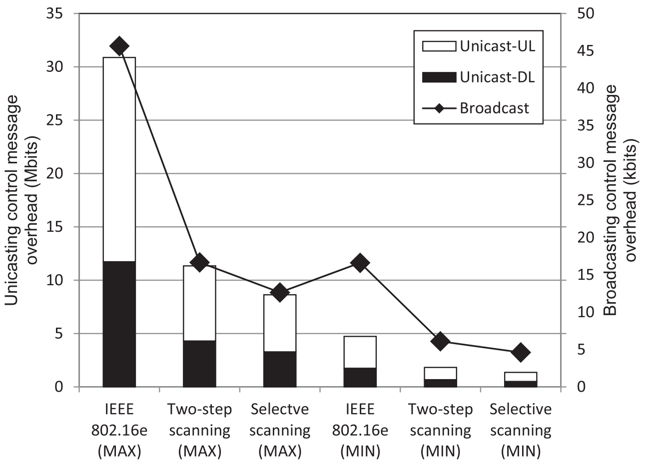

Fig. 3 Unicasting control message overhead and broadcasting control message overhead.

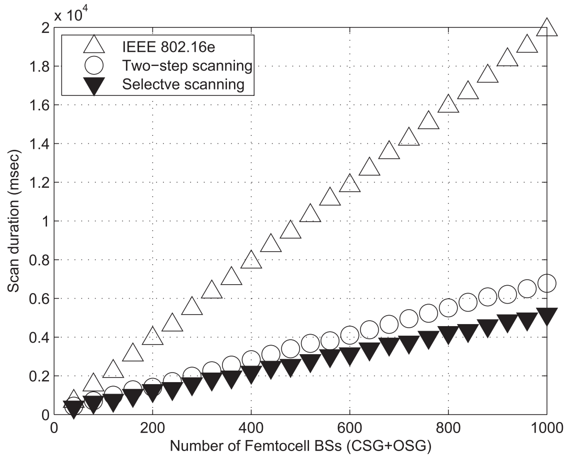

Fig. 4 Scan duration.

is independent of the number of neighboring cells. The other part consists of message fields containing information of neighboring cells, such as Neighbor_BS_Index, Scanning type, Rendezvous time, etc. The size of second part is proportional to the number of neighboring cells. We calculated the maximum and minimum control message overhead because of some optional fields in the control messages [1].

From Fig. 2, it is shown that the proposed scheme reduces the total control message overhead by 73.5% compared with the IEEE 802.16e scanning scheme, and by 25.4% compared with the two-step scanning scheme. Figure 3 shows the unicasting and broadcasting control message overhead when the number of femtocell BSs is 500. It is shown that the proposed scheme reduces the unicasting control message overhead by 72.1% compared with the IEEE 802.16e scanning scheme, and by 25.7% compared with the two-step scanning scheme. The broadcasting control message overhead of the proposed scheme is 27.7% of the IEEE 802.16e scanning scheme, and 75.7% of the two-step scanning scheme. The proportion of the uplink message overhead is about 62% of the total unicasting control message overhead, regardless of scanning scheme. This is because the number of uplink and downlink message is two and one, respectively.

3.2 Scan Duration

We define a scan duration as the time period between the start of scanning and the end of scanning, as is shown in Fig. 1. The scan duration can be obtained as follows [10].

Let T_{sync} denote the sum of the time needed to scan all of the scanning target cells. Since it usually takes two frames for synchronizing with a BS and for measuring the signal strength of the BS, T_{sync} can be obtained by

$$T_{sync} = 2 \times T_{frame} \times N_{scan}, \tag{1}$$

where T_{frame} is the frame length, and N_{scan} is the number of the cells to be scanned. The number of measurement intervals N_s can be calculated by

$$N_s = \left\lceil \frac{T_{sync}}{T_{measure}} \right\rceil, \tag{2}$$

where $T_{measure}$ is the maximum length of the measurement interval and $\lceil x \rceil$ means the smallest integer not less than x. Now the scan duration T_{total} can be obtained by

$$T_{total} = T_{sync} + (N_s - 1)\,T_{normal}, \tag{3}$$

where T_{normal} is the maximum length of the interleaving interval. The parameters are referred from the IEEE 802.16e system and we set T_{frame} to 5 ms, $T_{measure}$ to 150 ms, and T_{normal} to 150 ms [1], [10]. The computed scan durations are shown in Fig. 4. We found that the proposed scheme reduces the scan duration by 73.4% compared with the IEEE 802.16e scanning scheme, and by 23% compared with the two-step scanning scheme.

3.3 User Throughput

The user throughput can be obtained from the scan duration. A simple form of the user throughput R can be expressed as

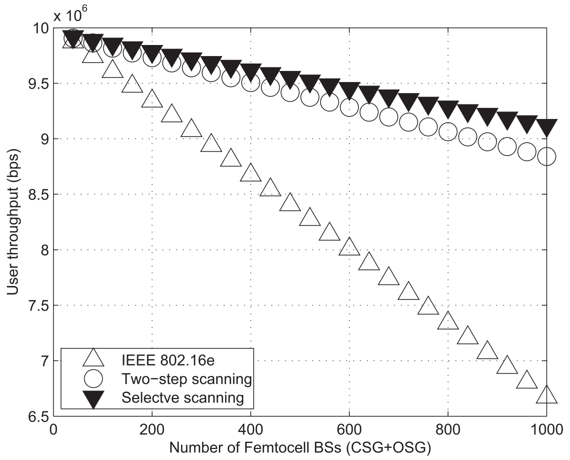

Fig. 5 User throughput versus number of femtocell BSs.

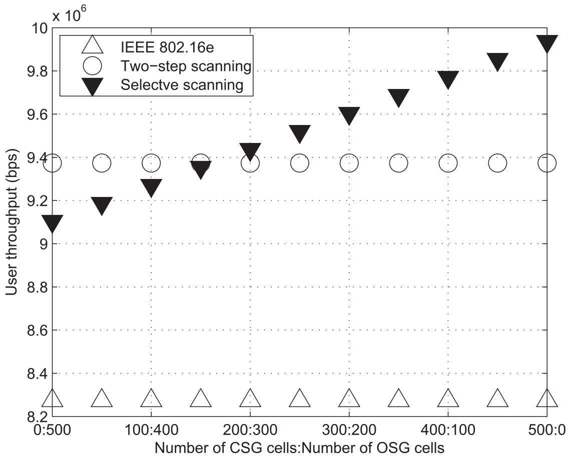

Fig. 6 User throughput versus number of CSG and OSG femtocells.

$$R = \left(T_l - T_{sync}\right) \times D/T_l, \tag{4}$$

where T_l is the observation duration, and D is the data rate. We set T_l to 30sec, and D to 10 Mbps.

From Fig. 5, it is shown that the proposed scheme increases the user throughput by 37.8% compared with the IEEE 802.16e scanning scheme, and by 3.3% compared with the two-step scanning scheme. Figure 6 represents the user throughput versus the number of CSG and OSG femtocells, when the sum of the number of CSG and OSG femtocells is 500. Since IEEE 802.16e scanning scheme and two-step scanning scheme do not consider the CSG and OSG femtocells separately, user throughput is constant. Proposed scheme shows better throughput performance than the other two schemes when the proportion of the CSG femtocells is greater than 40%. Thus, it is expected that the proposed scheme is effective in a macrocell where the CSG femtocells are more densely deployed.

4. Conclusions

In this letter, a selective scanning scheme for both CSG and OSG femtocells were presented. The proposed scheme can achieve lower scanning overhead because the MSs scan only the most available femtocells rather than all of the femtocells in the macro cell. Numerical results showed the efficiency of the proposed scheme in terms of the control message overhead, the scan duration, and the user throughput. The proposed scheme can be further used in other systems employing scanning operation such as the IEEE 802.16m system and the 3GPP LTE system.

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